APPENDIX B.22
OFFSITE DOSE CALCULATION MANUAL
FOR GENERAL ELECTRIC - MORRIS OPERATION

B.22.1 INTRODUCTION

This manual presents methods for calculating doses to members of the public from releases of radioactive material from General Electric Morris Operation (GE-MO). The methods employ values of wind speed, stability, and average X/Q taken from 1992 site meteorological data as typical of local conditions. This is simpler than using real time meteorological conditions and on-line calculations, and can be justified because the doses which could occur from credible releases are a small fraction of those allowed by regulation. For doses as small as these, the effort required to obtain the more sophisticated on-line analyses is not cost effective.

The low value of credible doses which could be received from accidental releases from GE-MO is illustrated by information taken from the Consolidated Safety Analysis Report[1](CSAR). This is shown as follows:

Type of Accident	Whole Body Dose (mRem)
Fuel Bundle Drop	2.0×10^{-2}
Fuel Basket Drop	8.1×10^{-2}
Tornado Missile	8.0×10^{-1}

In addition, the doses from normal operations have been calculated, based on the annual quantities of radionuclides released from the site over the past 10 years (1983 through 1992). These values are shown as follows:

Radionuclide	Maximum Annual range	Off-Site Dose (mRem) average
H-3	2.4 to 6.8×10^{-7}	4.4×10^{-7}
Co-60	0.39 to 2.0×10^{-8}	1.2×10^{-8}
Kr-85	1.0 to 1.6×10^{-5}	1.4×10^{-5}
Cs-134	0.18 to 1.6×10^{-9}	5.6×10^{-10}
Cs-137	0.01 to 5.8×10^{-8}	1.9×10^{-8}

These values are also many orders of magnitude below both regulatory limits and default values used to evaluate the achievement of ALARA goals (10 mRem/year according to Draft Regulatory Guide DG-8013[2]).

The methods are divided into three categories. The first category includes the methods for determining releases during normal operations and is based on measurement of stack samples or calculations of volumes of air released. Doses found using these methods are the annual doses which would be received by a member of the public at the worst off-site location.

The second category includes the methods used to calculate doses from a accidental ground level release. These methods require a measurement or estimate of the quantity of each radionuclide released, and give the dose to the nearest resident (assuming conservatively that the wind is in the direction of that nearest resident at the time of the accident). For a ground level release the nearest resident down wind receives the highest dose. The dose to that resident can be determined for worst case meteorological conditions, or more typical conditions.

The third category consists of similar methods for determining the dose from an accidental release through the 300 ft. stack. Again, a determination of the amount of material released is needed. With this given, the methods allow the calculation of the dose to a member of the public who remains at the worst off-site location for the duration of the release. The dose can be determined for the worst meteorological conditions, or average conditions.

Appendices of the manual give a tabulation of the parameters used to calculate values of X/Q for accidental releases, the variation of stability classes and wind speeds seen on-site in 1992, and justification for using neutral condition X/Q values for more stable conditions when considering releases via the 300 ft. stack.

B.22.2 NORMAL CONDITIONS

The off-site dose under normal conditions is considered to be the result of chronic releases from the 300 ft. stack. This is approximated by assuming a uniform release rate over a period of a year. Three factors must be known to compute the dose, the atmospheric dispersion (X/Q in sec/m^3), the dose per μCi inhaled (Rem/μCi), and the average rate of release.

The atmospheric dispersion has been determined experimentally over a number of years as part of the joint GE-CECO meteorological monitoring program conducted at the adjacent Dresden Nuclear Power Station (DNPS). The value of the atmospheric dispersion used in this manual is the maximum offsite relative concentration (X/Q) for 1992. That value, 7.88×10^{-8} sec/m^3, is typical of those seen for the annual periods over the past 20 years.

The dose per μCi inhaled (dose conversion factor) (Rem/μCi) is taken directly from the "Internal Dose Conversion Factors for Calculation of Dose to the Public", DOE/EH 0071[3] for the individual radionuclide inhaled. The concentration in the air breathed is multiplied by the quantity breathed (22,800 liters per day for the Standard Man) and this dose conversion factor.

The average activity released over a year is determined differently depending on whether the radionuclides released are particulates, krypton-85 (Kr-85), or tritium (H-3) (as HTO).

Particulates: The basis for determining the dose from the chronic release of particulates is the result of the stack sampler composite analysis. Weekly air samples are collected from Loops 1 and 2 of the stack sampler, and composited. At the end of six months each composite is analyzed for gamma emitting radionuclides using a germanium detector. The highest activity of a radionuclide (from analysis of the Loop 1 or Loop 2 composite) during the first six month period is added to the highest value for that radionuclide during the second six months. The total (referred to as the total quantity sampled) is a conservative assessment of the amount of that radionuclide that passed through a sample loop during the year.

The activity of the radionuclide released is found by multiplying that total by the ratio of flows, ((in the stack) to (in a sample loop)). This number is typically about 24,000, the stack flow rate (12,000 ft^3/min.) divided by the loop flow rate (0.5 ft^3/min.). The product of the total quantity sampled and this ratio gives the quantity of that radionuclide released in the year (in μCi). The average release rate in Ci/sec. is determined by dividing this value by the number of seconds per year and converting μCi to Ci.

Equation 1 gives the average concentration (Ci/m^3 or $\mu Ci/cm^3$) of any radionuclide released in particulate form at the worst off-site location.

$$\text{Average Concentration} = (A_1+A_2)(\text{Flow ratio})(X/Q)/3.15 \times 10^{13} \quad (1)$$

Here A_1 is the activity in μCi of the radionuclide of interest on the stack sampler composite for the first half of the year (The highest value of Loop 1 and Loop 2). A_2 is the same value for the second half. 3.15×10^{13} is the conversion from μCi/yr. to Ci/sec.

Equation 2 gives the annual committed effective dose equivalent (in Rem) which could result from this radionuclide if a person were to occupy the worst off-site location for a year's duration.

$$\text{Annual CEDE} = 8.32 \times 10^{9}\,(\text{Aver. conc.})(\text{Dose conversion factor}) \quad (2)$$

The average concentration is taken from Equation 1, and dose conversion factor (in Rem/μCi) is from DOE/EH 0071. 8.32×10^9 is the cm^3 of air breathed in a year by the standard man.

Kr-85: The basis for determining the dose from the chronic release of Kr-85 is the measurement of that radionuclide in the air over the basin. This was originally done in 1980. The concentration[4] was found to be 5.8×10^{-8} $\mu Ci/cm^3$. More recently, in 1992, two additional measurements were made, one over each basin. They averaged 3.8×10^{-8} $\mu Ci/cm^3$. The agreement between the two indicates that the release rate can be considered to be constant. For this manual the higher of the two values is used.

The concentration in the basin air is multiplied by the flow rate into the basin exhaust plenum to get the rate of release, and this value is multiplied by X/Q to get the concentration at the worst off-site location. The calculation of this worst average off-site concentration (Ci/m^3 or $\mu Ci/cm^3$) is shown in Equation 3.

$$\text{Kr-85 off-site concentration} = 4.72 \times 10^{-4}\,(C)\,(\text{Flow rate})\,(X/Q) \quad (3)$$

Here "C" is the concentration of Kr-85 over the basin in $\mu Ci/cm^3$, and "Flow rate" is the air flow rate through the basin exhaust plenum in $ft.^3$/min., (typically 7,500 $ft.^3$/min.). 4.72×10^{-4} converts the product from ($\mu Ci/cm^3$)($ft.^3$/min.) to Ci/sec. The whole body and skin doses which would be incurred from occupying the area of highest off-site concentration are determined from Equations 4 and 5 respectively.

Kr-85 skin dose (mRem/yr.) = 10^6 (Off-site conc.) (Skin dose factor) (4)

The skin dose factor is taken directly from the "External Dose-Rate Conversion Factors for Calculation of Dose to the Public," DOE/EH 0070[5]. It is 1.58×10^3 (mRem/yr.)/(μCi/m^3) for Kr-85.

Kr-85 deep dose (mRem/yr.) = 10^6 (Off-site conc.) (Deep dose factor) (5)

The deep dose factor is taken directly from DOE/EH 0070. The value is 1.12×10^1 (mRem/yr.)/(μCi/m^3) for Kr-85.

H-3: The basis for determining the annual dose from the chronic release of H-3 is the measured concentration of H-3 in the basin and the amounts of water released from this reservoir during the year. Concentrations of H-3 in the basin are determined periodically as part of the Operability Test/Compliance Test system. The volumes of water released are determined from operating records for basin make-up water added during the year. Equation 6 gives the average concentration of tritium (Ci/m^3 or μCi/cm^3) at the worst off-site location.

H-3 off-site concentration = $(C_1V_1)(X/Q)/3.15 \times 10^{13}$ (6)

Here C_1 is the average H-3 concentration in basin water (μCi/cm^3) and V_1 is the volume of basin make-up water added in the year in cm^3, 3.15×10^{13} is the same conversion used in Equation 1. The whole body committed effective dose equivalent (Rem) which would be incurred from occupying the area of highest off-site concentration is determined from Equation 7.

Annual CEDE = 8.32×10^9 (Off-site conc.)(Dose conversion factor) (7)

The dose conversion factor for H-3, taken from DOE/EH 0071, is 6.3×10^{-5} Rem/μCi.

B.22.3 Accident Conditions (General)

The off-site dose under accident conditions depends on the quantity of each radionuclide released, the release point (ground level or 300 ft.), and the meteorological conditions. The amount of each radionuclide released is estimated or measured at the time of release. Analyses made to support the Consolidated Safety Analysis Report (CSAR) give some conservative estimates for releases which could occur as the result of credible accidents at GE-MO. Examples of some of the amounts which could be released according to the CSAR are shown as follows (worst case PWR or BWR used):

Fuel Bundle Drop	1.530×10^3 Ci noble gases (PWR) and 3.3×10^{-7} Ci iodines (BWR)

Fuel Basket Drop	6.156×10^{3} Ci noble gases (BWR) and 3.01×10^{-6} Ci iodines (BWR)
Tornado Generated Missile	3.7×10^{3} Ci noble gases (PWR) and 1.8×10^{-6} Ci iodines (PWR)

Because of the age of the fuel stored at GE-MO the noble gases are assumed to be all Kr-85, and the iodines all I-129. For a similar reason Cs-137 will be used instead of Cs-134.

The release point for the various kinds of accidents is known because of the features of the facility. Radionuclides released from events which occur in the basin or the process building such as the fuel bundle and basket drops exit through the sand filter and the 300 ft. stack. Radionuclides released by evaporation or by tornado (which would destroy the integrity of the metal building covering the basin) were assumed to be ground level releases.

The dispersion of the released material due to air movement is given by Equation 8.

$$X = \left(\frac{Q}{2\pi\sigma_z\sigma_y\mu_h}\right)\exp-\left(\frac{z^2}{\sigma_z^2}+\frac{y^2}{\sigma_y^2}\right) \qquad (8)$$

Here "X" is the average air concentration (Ci/m^3 or μCi/cm^3) at any selected point, and "Q" is the release rate in Ci/sec. "u_h" is the average wind speed at the height of the release, and "σ" is the standard deviation of the cloud width in the horizontal (y) direction and vertical (z) direction. "y" and "z" are horizontal and vertical distances from the centerline of the plume, and "t" is the time after the release. Therefore the distance (x) from the point of release to the selected point is the product of u_h and t.

For purposes of this manual cloud depletion is not considered and the dose is figured to a person directly downwind of the release. Therefore "y = 0". For a ground level release "z = 0" also. Under these conditions Equation 8 can be simplified. This simplified expression is shown as Equation 9.

$$\frac{X}{Q} = \frac{1}{\left(2\pi\sigma_z\sigma_y\mu_h\right)} \qquad (9)$$

Watson and Gamertsfelder[6] also give equations to determine σ_y and σ_z. These are repeated as Equations 10, 11, and 12.

$$\sigma_y^2 = \left(C_y\right)^2 x^{(2-n)/2} \qquad (10)$$

$$\sigma_z^2 = \left(C_z\right)^2 x^{(2-n)/2} \qquad \text{(neutral and unstable case)} \qquad (11)$$

$$\sigma_z^2 = a\left(1 - \exp\left(-k^2 t^2\right)\right) + bt \qquad \text{(stable case)} \qquad (12)$$

Parameters needed to solve these equations are given for four stability classes and several wind speeds in the FSAR[7], and repeated in Appendix 1 to this manual. The fraction of the time that each condition (wind speed and stability class) was observed during the reference period (1992) according to Murray and Trettel[8] is reproduced in Appendix 2. As shown in the following table the range in the lapse rate for each class was used to establish the relationship between the four classes of the FSAR and these seven classes:

FSAR Stability Class	Lapse Rate	M&T Stability Class
Unstable	< - 1.5 °C	EU + MU + SU
Neutral	- 1.5 to - 0.5 °C	N
Moderately Stable	- 0.5 to 1.5 °C	SS
Very Stable	> 1.5 °C	MS + ES

Appendix 2 to this manual gives the fractional time that each FSAR stability class and each wind speed were prevalent during 1992.

No consideration is given in this manual to variations in wind direction. It is assumed that when the accidental conditions exist, the wind is blowing straight towards the most likely exposed member of the public. For ground level releases, this is the closest individual. For elevated releases this is the individual at the distance where (X/Q) is maximum.

The following sections determine the atmospheric dispersion (X/Q) based on the parametric values originally provided in the FSAR for different release points (ground level and 300 ft.), wind speeds, and stability classes. These values are then matched with the corresponding prevalence of each atmospheric condition (from M&T) to determine the most likely (X/Q), the median (X/Q), and the maximum (X/Q) that would be expected.

B.22.4 Accident Conditions - (Ground Level Release)

The maximum concentration from a ground level release is to the nearest neighbor, and his residence is about 508 m east of the process building. The concentration at this worst location was determined by using the parameters in Appendix 1 to compute σ_y and σ_z for each of the four stability classes, and for wind speeds of 2.25, 5.5, 10, 15, 21, and >24.5 mph. Then Equation 9 was used to compute X/Q. Table B.22-1 gives the X/Q values for each atmospheric condition.

TABLE B.22-1
MINIMUM ATMOSPHERIC DISPERSION for a GROUND LEVEL RELEASE

Wind Speed (m/h)	Unstable	Neutral	Moderately Stable	Very Stable
1 - 3.5	3.47 E-5	1.63 E-4	3.83 E-4	9.17 E-4
3.6 - 7.5	1.42 E-5	6.68 E-5	1.97 E-4	4.07 E-4
7.6 - 12.5	1.07 E-5	6.24 E-5	1.23 E-4	2.31 E-4
12.6 - 18.5	7.11 E-6	4.16 E-5	9.39 E-5	1.56 E-4
18.6 - 24.5	5.83 E-6	3.43 E-5	8.08 E-5	1.12 E-4
> 24.5	4.53 E-6	2.66 E-5	7.44 E-5	8.74 E-5

When this table is combined with the data in Appendix 2 (which has been condensed to match the four stability classes found in the FSAR) one can determine the distribution of expected X/Q values. This is shown in Table B.22-2.

TABLE B.22-2
DISTRIBUTION OF EXPECTED VALUES OF ATMOSPHERIC DISPERSION
for a GROUND LEVEL RELEASE

X/Q	Cum %	X/Q	Cum %	X/Q	Cum %
9.17 E-4	00.00	1.12 E-4	20.33	3.47 E-5	76.19
4.07 E-4	00.62	9.39 E-5	21.38	3.43 E-5	76.25
3.83 E-4	02.49	8.74 E-5	31.87	2.66 E-5	83.92
2.31 E-4	02.91	8.08 E-5	31.88	1.42 E-5	86.79
1.97 E-4	06.10	7.44 E-5	36.12	1.07 E-5	89.53
1.63 E-4	08.00	6.68 E-5	36.96	7.11 E-6	94.23
1.56 E-4	08.95	6.24 E-5	43.18	5.83 E-6	98.51
1.23 E-4	13.28	4.16 E-5	59.06	4.53 E-6	99.80

In Table 2 "Cum %" refers to the percent of the time that a larger value of X/Q would be expected based on the 1992 data. A review of this table shows, based on 1992 data, that the worst case X/Q for a ground level release is 9.17×10^{-4} sec/m^3. In addition, the median and most frequent X/Qs are found to be 4.16×10^{-5} sec/m^3.

The values from Table 2, when combined with the credible releases identified in the CSAR allow one to calculate the doses that the person occupying the residence at the worst off-site location would receive. In each case it is assumed that person is exposed for the entire duration of the release. The necessary calculations are made using Equations 13 through 16.

Deep dose from Kr-85 (Rem) = 3.17×10^{-5} (X/Q)(Ci released)(1.12×10^{1}) (13)

Here 3.17×10^{-5} converts mRem to Rem, years to seconds and Ci to µCi; and 1.12×10^{1} gives the deep dose in mRem per yr. from immersion in a cloud of Kr-85 with a concentration of 1.0 µCi/m^3 (from DOE/EH 0070).

$$\text{Skin dose from Kr-85 (Rem)} = 3.17 \times 10^{-5} (X/Q) (\text{Ci released}) (1.58 \times 10^{3}) \quad (14)$$

This equation is the same as Equation 13 except for the dose conversion factor of 1.58×10^{3} (mRem/yr.)/(µCi/m^3) to the skin (from DOE/EH 0070).

$$\text{CEDE from I-129 (Rem)} = 2.64 \times 10^{2} (X/Q)(\text{Ci released})(0.18) \quad (15)$$

The factor 2.64×10^{2} is the volume of air breathed per second by the Standard Man (in cm^3). It comes from 22,800 L/day usually quoted in tables. 0.18 is the dose conversion factor for iodine-129 in Rem/µCi from DOE/EH 0071.

$$\text{CEDE from Cs-137 (Rem)} = 2.64 \times 10^{2} (X/Q)(\text{Ci released})(3.2 \times 10^{-2}) \quad (16)$$

This equation is similar to Equation 15, except that the dose conversion factor (3.2×10^{-2} Rem/µCi) is for Cs-137.

Conservative values of the maximum dose, the most likely dose, or the median dose can be calculated from these formulae depending on the value of X/Q chosen from Table 2.

For cases other than those quantified in the CSAR, the amount and kind of the radionuclides released needs to be measured or estimated. The amount of each radionuclide released is substituted into Equation 13 to determine the external deep dose from immersion in the plume. Similarly, the use of Equation 14 will give the skin dose, and substitution into Equation 15 or 16 is for determining the CEDE. For radionuclides other than Kr-85, I-129 and Cs-137 appropriate dose conversion factors need to be found by referring to DOE/EH 0070 or DOE/EH 0071.

B.22.5 Accident Conditions -- (release at 300 ft.)

The maximum concentration from a release at an elevation of 300 ft. occurs at the center of the plume, downwind, at a distance that depends on the meteorological conditions. The distance and the maximum X/Q can be determined from Equation 8 for unstable and neutral conditions as shown in the following text. It is subsequently shown that the maximum X/Q for stable and very stable conditions is lower than X/Q for neutral or unstable conditions. Therefore, the value for neutral conditions can be used as a conservative estimate of X/Q for more stable conditions.

The distance where X/Q is maximum is determined by differentiating Equation 8 with respect to "x" and setting the result equal to 0. Since one is interested in the value at the plume centerline, y = 0, and half of the exponential term drops out. Equation 17 gives the expression for determining the downwind distance (in meters) where X/Q is maximum.

$$x^{(n-2)} = \left(\frac{C_z}{z}\right)^2 \qquad (17)$$

"z" is the stack height (no credit is taken for plume rise), and "C_z" is the value from Appendix 1 for the meteorological condition considered.

Once "x" is determined, it can be substituted into Equation 8 to calculate X/Q. This calculation was done for each of the wind speed categories shown in Table 1 for both neutral and unstable conditions. The results are shown in Table 3.

TABLE B.22-3
MINIMUM ATMOSPHERIC DISPERSION for a RELEASE at 300 feet

Wind Speed (m/h)	Unstable X/Q (sec/m^3)	Distance (m)	Neutral X/Q (sec/m^3)	Distance (m)
1 - 3.5	6.94 E-6	575	6.94 E-6	1523
3.6 - 7.5	2.85 E-6	575	2.85 E-6	1523
7.6 - 12.5	1.57 E-6	674	1.57 E-6	1965
12.6 - 18.5	1.04 E-6	674	1.04 E-6	1965
18.6 - 24.5	7.47 E-7	737	7.47 E-7	2170
> 24.5	5.80 E-7	737	5.80 E-7	2170

For moderately stable and very stable conditions the differentiation of Equation 8 is more difficult, since Equation 12 must be used to express σ_Z. However, it can be shown that X/Q for a release at 300 ft. for the stable cases is always less than the X/Q for the neutral case. Appendix 3 gives an example showing that this relationship exists. This relationship allows the X/Q for a given wind speed and neutral conditions to be used conservatively for the moderately stable and very stable conditions. Table 4 gives the cumulative distribution of X/Q values for the 300' release based on using neutral condition X/Q values for more stable weather.

TABLE B.22-4
DISTRIBUTION of EXPECTED VALUES of ATMOSPHERIC DISPERSION for a RELEASE at 300 feet

X/Q	Cum %	X/Q	Cum %	X/Q	Cum %
6.94 E-6	00.00	1.57 E-6	14.78	7.47 E-7	81.80
2.85 E-6	02.05	1.04 E-6	45.59	5.80 E-7	96.25

In this table as well as in Table 2 "Cum %" refers to the percent of the time that a larger value of X/Q would be expected based on the 1992 data. A review of Table 4 shows, based on 1992 data, that the worst case X/Q for a release at 300 ft. is 6.94 x 10^{-6} sec/m^3. In addition, the median X/Q and the most frequent X/Q are found to be 1.04 x 10^{-6} sec/m^3.

To calculate the dose that a person occupying the residence at the worst off-site location would receive from the release of Kr-85, I-129, Cs-137 at 300 ft. -- one measures or estimates the quantity released, selects the appropriate X/Q value from Table 4, and uses Equations 13 through 16. In each case it is assumed that the person is exposed for the entire duration of the release.

B.22.6 Accident Conditions (Summary)

Three steps are needed to compute the dose to a member of the public from accidents other that the four listed under "Accident Conditions (General)". First, one should decide if the release is from ground level or via the 300 ft. stack and select an X/Q value from Table 2 or 4 respectively. Secondly, the type and amount of radioactive material released should be determined (by measurement or estimation). Finally, these values should be substituted into Equations 13 or 14 (for doses via immersion) or Equations 15 or 16 (for doses via inhalation). For radionuclides other than Kr-85, I-129, and Cs-137 the appropriate dose conversion factors need to be found by referring to DOE/EH 0070 or DOE/EH 0071.

B.22.7 REFERENCES

1. Consolidated Safety Analysis Report, General Electric Co., NEDO 21326D7, Oct., 1996.

2. U.S. Nuclear Regulatory Commission Draft Regulatory Guide DG-8013, "ALARA Levels for Effluents from Materials Facilities," October, 1992.

3. Internal Dose Conversion Factors for Calculation of Dose to the Public, Department of Energy, DOE/EH 0071, July, 1988.

4. Judson, B.F., In-Plant Test Measurements for Spent Fuel Storage at Morris Operation, Volume 1, "Gaseous Radionuclides Release Rates", General Electric Co., NEDG 24922-1, May, 1981.

5. External Dose-Rate Conversion Factors for Calculation of Dose to the Public, Department of Energy, DOE/EH 0070, July 1988.

6. E. C. Watson and C. C. Gamertsfelder, Environmental Radioactive Contamination as a factor in Nuclear Plant Siting Criteria, February 14, 1963, (HW-SA-2809).

7. Final Safety Analysis Report, Midwest Fuel Recovery Plant, Morris, Illinois, General Electric Co., NEDO 10178, December, 1970.

8. "Semi-Annual Report on the Meteorological Monitoring Program at the General Electric - Morris Operation", Murray and Trettel, Inc., January-June, 1992.

APPENDICES

Appendix 1
Values of Atmospheric Variables

Variable	Release Height (m)	Wind Speed (m/sec)	Atmospheric Stability: Very Stable	Moderately Stable	Neutral	Unstable
a	all		34	97		
b	all		0.025	0.33		
K^2	all		0.0088	0.00025		
n	ground		0.3	0.3	0.25	0.20
n	300 ft.		0.4	0.4	0.25	0.20
C_y	ground	1 - 3	0.18	0.18	0.21	0.35
C_y	ground	4 - 7	0.18	0.18	0.15	0.30
C_y	ground	> 7	0.18	0.18	0.14	0.28
C_y	300 ft.	1 - 3	0.18	0.18	0.15	0.30
C_y	300 ft.	4 - 7	0.18	0.18	0.12	0.26
C_y	300 ft.	> 7	0.18	0.18	0.11	0.24
C_z	ground	1 - 3			0.17	0.35
C_z	ground	4 - 7			0.14	0.30
C_z	ground	> 7			0.13	0.28
C_z	300 ft.	1 - 3			0.15	0.30
C_z	300 ft.	4 - 7			0.12	0.26
C_z	300 ft.	> 7			0.11	0.24

Appendix 2
Distribution of Meteorological Conditions

				Stability Classes			
Wind Speed (m/hr)	**Extremely Unstable (EU)**	**Moderately Unstable (MU)**	**Slightly Unstable (SS)**	**Neutral (N)**	**Slightly Stable (SS)**	**Moderately Stable (MS)**	**Extremely Stable (ES)**
< 3	0.00	0.01	0.05	0.95	0.42	0.36	0.26
4 - 7	0.23	0.78	1.73	6.22	1.90	1.31	0.56
8 - 12	0.84	1.59	2.27	15.88	7.05	2.33	0.85
13 - 18	1.44	1.10	1.74	17.13	10.47	3.71	0.62
18 - 24	0.24	0.40	0.65	7.87	4.24	0.91	0.14
> 24	0.00	0.05	0.16	2.87	0.84	0.01	0.00

Appendix 3
Limiting X/Q for Moderately and Very Stable Conditions

The X/Q for neutral conditions can be used conservatively to represent the X/Q for moderately stable and very stable conditions because neutral condition X/Q is larger. This is demonstrated by computing σ_z for the four atmospheric condition classes for a 300 ft. release with a wind speed of 1.01 m/sec. It can be seen from this demonstration that the neutral condition X/Q is also larger for different distances and different wind speeds. σ_z is calculated for the distance of 575 m. listed in Table 3.

Unstable Conditions:

$$\sigma_z = \left(\frac{C_z^2 \left(x^{(2-n)} \right)}{2} \right)^{1/2} = \left(\frac{0.3^2 (575)^{1.8}}{2} \right)^{1/2} = 64.6$$

Neutral Conditions:

$$= \left(\frac{0.15^2 (575)^{1.8}}{2} \right)^{1/2} = 32.3$$

Moderately Stable Conditions:

$$\sigma_z = \left(a \left(1 - \exp\left(-K^2 t^2 \right) \right) + bt \right)^{1/2}$$

$$= \left(97 \left(1 - \exp\left(-0.00025 \left(\frac{575}{1.01} \right)^2 \right) + 0.33 \left(\frac{575}{1.01} \right) \right)^{1/2} \right) = 16.6$$

Very Stable Conditions:

$$= \left(34 \left(1 - \exp\left(-0.0088 \left(\frac{575}{1.01} \right)^2 + 0.025 \left(\frac{575}{1.01} \right) \right)^{1/2} \right) \right) = 6.94$$

X/Q varies with σ_z in the following way:

X/Q is proportional to:

$$\left(\frac{1}{\sigma_z} \right) \left(\exp - \left(\frac{\text{Constant}}{\sigma_z^2} \right) \right)$$

For a decrease in σ_z, X/Q decreases more rapidly.

For increasing X, the σ_z for unstable and neutral conditions increases more rapidly than for moderately and very stable conditions.

For increasing wind speeds, σ_z decreases for moderately and very stable conditions. σ_z for unstable and neutral conditions is unchanged.